NEED OF UNDERSTANDING HOW TO ENHANCE INNOVATION AT EARLY PHASES OF PRODUCTION SYSTEM DEVELOPMENT

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ABSTRACT

The main purpose this paper is to discuss a research potential in the area of understanding how a company can enhance innovation at the early phases of production system development. Due to this purpose, the structure of this paper deviates from the conventional ones that include methods, findings, and contributions. The chain of logic in this paper is structured as follows. Firstly, the importance of the early phases in terms of constantly developing new production systems is mentioned. Then, the early phases are defined and described in theoretical frameworks. Later, two industrial cases are introduced to emphases the aforementioned importance. Finally, the research potential is discussed based on the theories and practices introduced in the earlier parts of the paper.

BACKGROUND

The purpose of this paper is to discuss a research potential in the area of understanding how to enhance innovation at the early phases of production system development. Here, production system development is generally understood as identification, elaboration, and implementation of new system solutions in production. This section is to present the background of this discussion. The background is twofold. Firstly, the importance of building innovation capabilities in production is mentioned, and secondary it is discussed the importance of paying attention to the early phases of production system development as a way to improve the innovation capabilities.

INNOVATION CAPABILITIES IN PRODUCTION

In today's global business environment, it has become increasing harder for production functions of manufacturing companies to be constantly valuable for the companies. This is especially true for the functions located at high-wage countries. Those functions are exposed to ever growing competitive pressure from internal or external competitors located at lower-wage countries. In order for the functions at the high-wage countries to survive, they need to establish highly efficient production systems supported by active continuous improvement often done in an incremental and small-scale manner (Hill, 2005). Moreover, it is increasingly recognized as critical for the functions to obtain innovation capabilities, meaning the abilities of constantly developing new production systems that can radically improve certain performances (Smeds, 1997). Such abilities are difficult to be imitated by competitors, thus often considered valuable for the companies (Barney, 1991).

The importance of the innovation capabilities can be further emphasized by a result of a study conducted by the author of this paper. He conducted an interview study with several production related managers at Japanese manufacturing companies (Yamamoto, 2010). The study has shown that the managers considered internal or external competitors located in East and South East Asia as serious threats to the factories in Japan. The managers recognized that it had become hard for the factories to survive, as far as the role of the factories was only to produce goods and speed of improvement at the factories were similar to those at the competitors. They expressed that making the domestic factories the centres of production system development where novel and unique solutions were constantly developed, experimented with, and used in the factories was one of a few ways for the factories to survive in a long-term perspective. The challenge addressed by those managers seems to be relevant to other high-wage countries. In Sweden, for instance, several studies are conducted with the recognition of improving aforementioned innovation capabilities (Ahlskog et al., 2016; Frishammar et al., 2012; Gåsvaer et al., 2016; Södergren, 2016).

EARLY PHASES OF THE DEVELOPMENT

Although the importance of innovation capabilities in production can be recognized, the most of the research on the early phases of the development work has been done in the area of New Product Development (NPD). In this area, a variety of research stream exist, such as, structuring the process of NPD (e.g. Cooper, 1994) and understanding the effect of customer integration to NPD (von Hippel, 1986). The early phases of NPD, alternatively called Fuzzy Font-End (FFE) of NPD is another major steam of the research. The FFE is an early, ad-hoc, and less formal phases of development between the time when the opportunity is known and the time when a serious effort is devoted to the realization project (Smith and Reinertsen, 1998). Due to the high degree of freedom to explore new ideas in the phases, they are considered as critical phases to realize innovative products (Cooper and Kleinschmidt, 1994; Gassmann and Schweitzer, 2013; Markham, 2013). A statement from Gassmann and Schweitzer (2013) is representative; "the real leverage in bringing up new ideas and improving the competiveness of innovation lines in the front end of innovation".

Similar to the research on NPD, some researchers in the area of production have argued that the early phases of production system development are important to realize innovation production systems. For instance, Ahlskåg et al. (2015) state that establishing a process of early phases is important to facilitate the development of new production methods. Gåsver et al. (2016), through their case study at a manufacturing company, have concluded that organizational support to the early phases of the production system development was important for production engineers at the company to devote more time in generating and concretizing new ideas from a long-term perspective. Further, Yamamoto (2013), though his research on radical changes of production systems, have recognized that if companies would desire to realize innovative production systems as the results of change projects, the companies should broadly explore and concretize knowledge of new production methods, prior to initiating the change projects. In the third section of this paper, the importance is further strengthened by introducing two industrial examples from Toyota Group companies.

THEORETICAL FRAMEWORK

Before continuing the discussion on the early phases of production system development, it may be appropriate to frame terms and concepts related to the topic in this paper.

PRODUCTION SYSTEM DEVELOPMENT

In this paper, a production system is defined based on a definition suggested by Wu (2001): a collection of facilities, humans, and information working together in an integrated manner to make products from their material constitutes. The author of this paper considers that a production system corresponds to a production plant. A production system can be divided into subsystems[1] from different perspective. Examples of subsystems are assembly lines, production machines, work organizations, internal logistics, and planning and control systems.

In this paper, development of production system, or in short production system development, means development of an entire production system or some parts of the system. A literal meaning of development is elaborating things in detail (Oxford, 2003). Bellgran and Säfsten (2005) describe production system development as a set of activities between the time when an opportunity of building a new production system is recognized and the time when the new system runs in the operation. The activities include preparation for the design of new production system, conceptual design, detailed design, realization of the design, and production ramp- up. This paper shares the view of the production system development from those authors.

Innovative production system can be defined here too. In literature, innovation is often classified in terms of newness, for instance incremental or radical (Dewar and Dutton, 1986), or new to company or new to the industry (Garcia and Calantone, 2002). In the research project, an innovative production system is a production system that is new to the company to a high degree and at the same time is valuable for the company's competitiveness. According to Schroeder et al. (1989), innovation does not only mean new to the company but also contributing to the organizational objectives.

THE EARLY PHASES OF PRODUCTION SYSTEM DEVELOPMENT

The early phases of production system development is defined in this paper as the phases of development between the time when an opportunity of developing a new production system or parts of the system is known and the time when serious efforts are devoted to realization projects. This definition is based on the definition of the early phases of NPD suggested by

[1] In this paper, a subsystem at a lower level of a system hierarchy can be called a system component.

Smith and Reinertsen (1998) and Cooper (1994). At the end of the early phases of the production system development, conceptual designs of the systems with different levels of detail have been evaluated and waiting for go or no go decision for realization projects. Previous studies on the early phases of production system development (e.g. Gåsvaer et al., 2016) have indicated that the characteristics of the phases share many of those at the early phases of NPD. In the NPD research, the early phases are often described as ad-hoc, less structured, and ambiguous phases where the uncertainty is maximum (Gassmann and Schweitzer, 2013). Several researchers have observed that decisions made at the phases have high leverage for the whole innovation process (Kim and Wilemon, 2002; Reid and De Brentani, 2004). Their studies have shown that wrong decisions at the FFE may lead to costly and time- consuming deviations later on. At the same time, the scope of actions is high at those phases (Gassmann and Schweitzer, 2013), where developers have high degree of freedom to explore new ideas and concretize them though experiments. Thus, the phases have significant influence on the innovativeness of the outcome and its market success (Markham, 2013).

Previous research on the early phases of the development has identified uncertainty reduction is a key concept for the management of the phases. The ambiguous and less structural nature of the phases make mangers difficult to manage and make proper decisions during the phases. Structuring the activities in the phases to reduce uncertainty, in other words reducing uncertainties in work methods, has been proposed as a viable approach to improve the activities in the phases (Christiansen and Gasparin, 2016). In the research area of NPD, different process models of the phases have been suggested in the literature, for instance, a model based on stage- gate model (Cooper, 1994), a model emphasizing the iterative nature of activities in the phases (Koen et al., 2001). Generally, the research on the early phases of development in production has far less appeared in literature than that on NPD (Kurkkio et al., 2011; Lager et al., 2013). Even through, most of the effort in the former research seems to be devoted to structuring the process of the early phases. For instance, Kurkkio et al. (2011) has presented a process model of the early phases of process development in the process industry. Ahlskog et al. (2016) has presented a process model especially focusing on the early phase of production technology development in the manufacturing industry.

CONCEPTUAL MODEL OF THE EARLY PHASES

With the purpose of sharing the author's conception of the early phases of production system development in this paper, two tentative conceptual models of the phases are introduced as shown in Figure 1 and 2. They are based on the theories in the area of the early phases of NPD, and previous studies related to the early phases of production system development (e.g. Ahlskog et al., 2016; Gåsvaer et al., 2016; Yamamoto, 2013). The models are hypothetical and the appropriateness of the models needs to be further examined in later research.

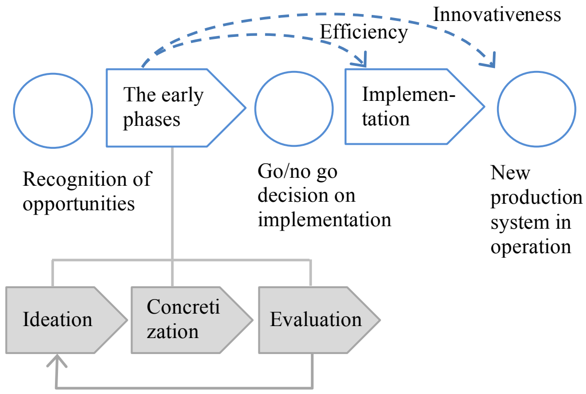

Figure 1: A generic process of production system development highlighting the early phases

Figure 1 is a generic process model of production system development highlighting its early phases. The model is a representation of the definition and characteristics of the phases mentioned earlier in this section. For instance, the model highlights that the early phases have a significant influence on the innovativeness of realized production system. As mentioned earlier, those phases are informal, ambiguous, and dynamic where variety of activities are undertaken in parallel (Cooper, 2011), and ideas and concepts at the end of the phases have different concreteness. Thus, those activities are difficult to be formalized (Murphy and Kumar, 1997). Despite to that, according to Griffiths-Hemans and Grover (2006), three basic activities are common to most of the early phases of the development, namely ideation, concretization, and evaluation. In the phases, ideas and concepts are generated, concretized through for instance experiments, and then evaluated. These basic activities are undertaken in an iterative manner through which maturity of the ideas and concepts are increased, some of which are discarded along with the iteration, until they are matured enough to receive go or no go decision for implementation (Koen et al., 2001).

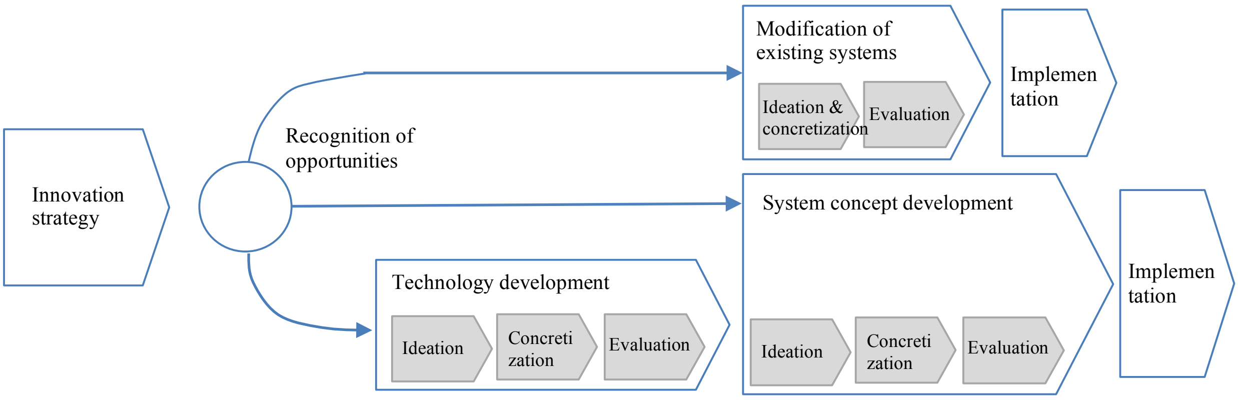

Figure 2: Holistic framework of the early phases of production system development (based on Gassmann and Schweitzer, 2013)

Another model shown in Figure 2 is a more holistic conceptualization of the early phases of production system development. The model is inspired by a framework of the early phases of NPD proposed by Gassmann and Schweitzer (2013). Similar to the framework of those authors, the model in Figure 2 has four scalable modules, namely innovation strategy, technology development, system concept development, and modification of existing system concept. Innovation strategy may not be considered as a part of the early phases but provide a context in which the phases are undertaken. In reference to the original framework, innovation strategy comprises all strategic statements on development of new production systems and technologies. By the analogy of the original framework, the innovation strategy can closely link to the company's production strategy which is often expressed with long-term goals in terms of competitive factors. Top management's commitment on how much resources are allocated to the early phases affects the performance at the phases (Gassmann and Schweitzer, 2013; Tidd et al., 2005). Thus, making such commitment is relevant to the strategy. Furthermore, a company may have a specific group or division devoted to the early phases of development. A case study done by Gåsvaer et al. (2016) indicates that it is important to clarify their roles, goals, and how to evaluate their performance. Having such clarification can be also relevant to the module.

After recognition of development opportunities, some projects may become technology development (see Figure 2) where involves identification, experiment, and evaluation of new technologies, for instance, on wielding, machining, etc. Such development often takes place at a component level of a system and its deliverable is certain technical capabilities (Cooper, 2006). Some projects are devoted to identification, concretization, and evaluation of new system concepts. Some other projects are to modify or refine existing system concepts. In such projects, identification, concretization, and evaluation are taken place less extensively than development of new system concept.

ILLUSTRATIVE CASES

The early phases of the production system development play an important roles in constantly developing new production systems. To further strengthen this point, two industrial examples are introduced. Empirical data of these two cases are collected when the author in this paper conducted a series of interviews with production related managers at manufacturing companies (Yamamoto, 2009, 2010). The common theme of the interviews was how to realize innovative production systems. The two cases are from two Japanese companies belong to Toyota Group. The companies are known for their sustained effort to make their factories advanced and competitive (e.g. Liker, 2004).

CASE 1

During the discussion of how to realize innovative production systems, an ex-senior manager at one of the case companies described how industrialization projects are organized at the company. He worked as a production engineer at the company for many years:

…We (production engineers) engage in industrialization projects to launch new car models in every year or two (see Figure 3, which is based on the figure drawn by the ex- senior manager during the discussion). There are a set of performance measures for those projects, such as project lead- time, defect rate, productivity, and investment cost in the new production lines. In each project, the management usually requires to improving the overall performance of the project by 30 to 40 percent. To achieve the targets, for example in the Model C project (in Figure 3), while we work for the industrialization project for Model A, we often go out and meet shop floor operators, engineers at R&D, academics, and/or industrial personals at other companies, in order to collect and identify new information and ideas. Then we frequently perform experiments on the new ideas and concepts. Some of them grow mature enough to be used in the project for Model C, but some others may be discarded or continue to be developed so that they can be implemented in later projects. Nonetheless, I think we test anything that has any potential, while each industrialization projects usually goes very fast once started…(Yamamoto, 2010).

The ex-senior manager also mentioned that the engineers used internally devised methods and tools to support the development work at the early phases, such as patent mapping to analyse technology trends, and core-technology matrix (products versus process technologies available at the company) that helps to transfer certain process technologies to other products. He also mentioned that the company's management tended to communicate to the production engineers that the engineers' roles is to change and not to keep the status of quo. For instance, even when using the same machine for another industrialization project, the management required to improve the value of the machine by 20 percent, through reducing the cost of the machine, increasing the capacity of the machine, and so forth.

In order to highlight the role of the early phases of the development in Case 1, a brief analysis of the case can be made. The description of the case implies that the production engineers take significant amount of effort at the early phases of production system development, in order to constantly create various sets of knowledge through the iteration of identification, concretization, and evaluation of new ideas and concepts. A conceptualization of this can be resemble to the model of Lean Product Development presented by Kennedy et al. (2008). The model is shown in Figure 4. These authors, through the analysis of Toyota's product development projects, have identified that the company put a large amount of development effort in the knowledge value steam (see Figure 4) where variety of knowledge, termed as set-based knowledge by Kennedy et al. (2008), is constantly created at the early phases of the NPD projects. It can be considered that in Figure 3 there is some kind of knowledge value stream lying in front of the industrialization projects.

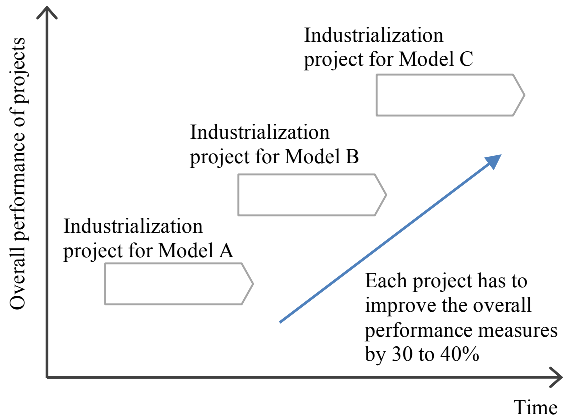

Figure 3: Industrialization projects at a case company (based on the figure drawn by the ex-senior manager of the company)

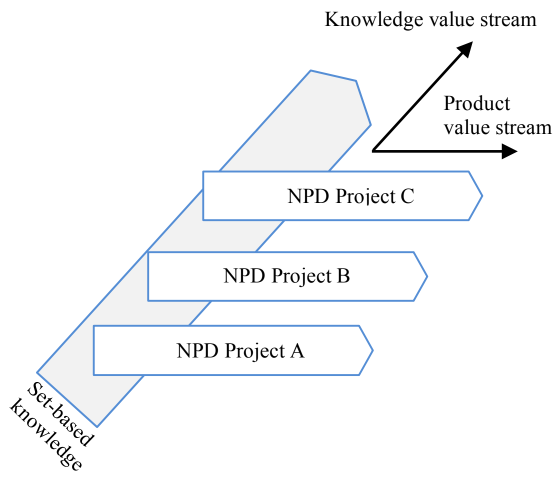

Figure 4: A model of Lean Product Development highlighting the knowledge value stream (based on the model presented by Kennedy et al. 2008)

CASE 2

An interview respondent at the other case company was a manager at one of the production engineering functions. He explained that the company had a long history of simultaneous engineering (Thomke and Fujimoto, 2000) since 1970's. Along with a long-term product roadmap, the company organized joint development teams called "next generation teams" (see Figure 5). In each team, product development engineers and production engineers closely work together to develop future product platforms as well as future generation of production systems. The manager mentioned that those production engineers were free to move their workstations to any other departments or business units within the company, depending on the project that they are involved.

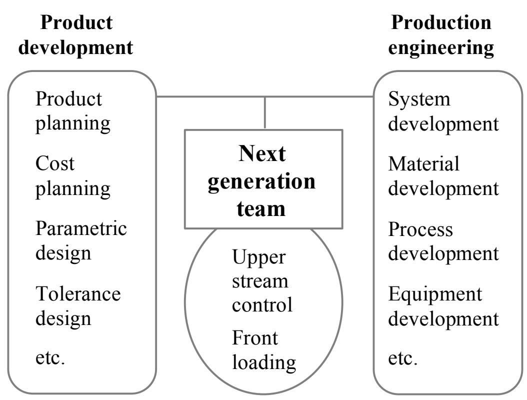

Figure 5: Next generation team explained in the case company's material

As a result of the next generation teams, a number of new production systems are developed and implemented in the factories as shown in Figure 6. Similar to Case 1, the respondent mentioned that the management tended to communicate to production engineers that their role is to come up with solutions that multiples the current performances, not to improve them by some percent. He also mentioned an initiative called "aha-activity". In the initiative, production engineers attended regular meetings where they share manufacturing methods learned from other industries (e.g. how machines peal a large numbers of apples in food processing factories), in order to identify new ways of manufacturing the products they are responsible for.

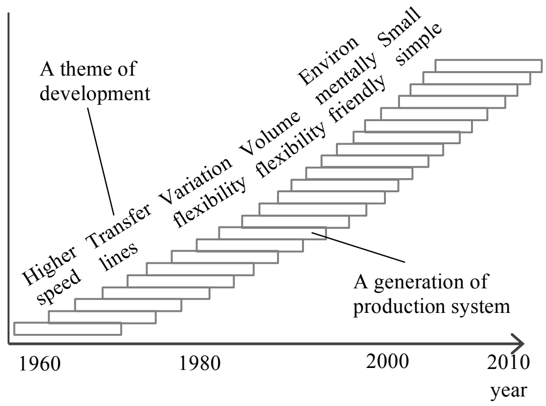

Figure 6: Generations of production systems developed at the case company (based on the figure presented in a case material, simplified for the purpose of this paper)

KNOWLEDGE GAP

The two cases in the previous section are introduced with the purpose of showing that the early phases play an important role to constantly develop new production systems. In this paper, these cases are also meant to serve another purpose. It is to address a knowledge gap in the current research on the early phases of production system development.

In addition to the cases showing the aforementioned role, the cases also indicate that these companies deliberately enhance explorative work in an organized manner at the early phases of the development. For instance, the analysis of Case 1 has implied that the company employs a cross-project management approach where new ideas and concepts are constantly created, concretized, evaluated, and accumulated in the knowledge value stream. In both cases, the management has been explicit about the roles of the production engineers as those who bring about radically new solutions. These companies also prepare tools and other activities that support explorative work at the phases.

The author of the paper argues that the question of how a company can, in an organized manner, enhance explorative work at the early phases of production system development has been largely unexplored in the current research. As mentioned in the section of theoretical framework, the research on the early phases of the production system development is still scarce and the most of the research has been devoted to structuring the process of the phases. Considering the ambiguity of the phases and the current maturity of the research on them, this paper acknowledges the importance of structuring the process in the phases in order to make the phases more transparent and thus manageable. On the other hand, in the research area of NPD, it has been discussed that the early phases of development is a balancing act between exploiting existing capabilities and dynamically exploring new ones, and between enforcing discipline and embracing creativity (Gassmann and Schweitzer, 2013). Christiansen and Gasparin (2016) state that structuring the process of the phases may be a viable strategy for control and efficiency. However, these authors also maintain that it does not necessarily accelerate exploration and concretization of new ideas and concepts at the phases for capturing emerging and unexpected opportunities. Therefore, in this paper it is maintained that more research is needed to increase the understanding of how an organization can enhance innovation at the early phases of production system development, along with the ongoing research on structuring the process.

In the research on the early phases of NPD, there are a variety of theories and practices on how to enhance explorative work at the early phases. Examples are, early integration of customers (e.g. von Hippel, 1986), cross- industry innovation by analogies (Gassmann et al., 2010; Herstatt and Kalogerakis, 2005), cross-project management to create set- based knowledge in the knowledge value stream (Kennedy et al., 2008), and acceleration of learning though rapid prototyping (Kelley and Littman, 2001; Thomke and Fujimoto, 2000). The applicability and the effect of those theories and practice to the early phases of production system development has been barely discussed in the current research. This is another research opportunity related to the knowledge gap mentioned earlier in this section.

Further, it may be considered that the two cases are extreme cases (Saunders et al., 2016), because these companies are known for their strive for making their production systems advanced and competitive. As discussed with Figure 2, innovation strategy of a company can significantly affect the explorative work at the early phases of production system development. Some other companies may have different strategies and thus require different approaches toward how to enhance innovation at the phases. Having better understanding of the relation between the strategies and the approaches is also another area that can be investigated further.

CURRENT RESEARCH ACTIONS

The chain of logic in the previous sections has been to accentuate the research potential of how a company can, in an organized manner, enhance explorative work at the early phases of production system development. In the autumn 2017, a research project has started to address this how-question. Current actions in the project are to collect, as much as possible, empirical data concerning how companies organize the early phases of production system development. The collected data are later analysed to identify how these companies support or hinder explorative work at the phases.

In the analysis, different analytical frameworks may be applied. For instance, Figure 1 shows that there are three basic activities in the early phases, which are ideation, concretization, and evaluation. The collected data can be sorted and analysed in the perspective of this classification. The two cases in a previous section imply that variety of acts and thinking in the early phases are related to different abstract level, from a principle and strategic level to a concrete and operational level. The collected data may be sorted and analysed in the perspectives of, for instance, principle and strategy, organizational structure and processes, and method and tools. Nonetheless, the project has started recently, research results are expected to be produced in future.

REFERENCES

Ahlskog, M. (2015), *Supporting Pre-Development of New Manufacturing Technologies*, Licentiate thesis, School of innovation, design, and engineering, Mälardalen University, Västerås, Sweden.

Ahlskog, M., Bruch, J. and Jackson, M. (2016), "Managing early manufacturing technology development phases and key activities", *23rd EurOMA Conference EUROMA 2016, 17-22 Jun 2016, Trondheim, Norway*.

Barney, J. (1991), "Firm Resources and Sustained Competitive Advantage", *Journal of Management*, Vol. 17 No. 1, pp. 99–120.

Bellgran, M. and Säfsten, K. (2005), *Produktionsutveckling- Utveckling Och Drift Av Produktionssystem*, Studentlitteratur, Lund.

Christiansen, J.K. and Gasparin, M. (2016), "Managing Controversies in the Fuzzy Front End", *Creativity and Innovation Management*, Vol. 25 No. 4, pp. 500–514.

Cooper, R.G. (1994), "Third Generation New Product Processes", *Journal of Product Innovation Management*, Vol. 11 No. 1, pp. 3–14.

Cooper, R.G. (2006), "Managing Technology Development Projects", *Research Technology Management*, Vol. 49 No. 5, pp. 23–31.

Cooper, R.G. (2011), *Winning at New Products: Creating Value Through Innovation*, Basic Books, New York.

Cooper, R.G. and Kleinschmidt, E.J. (1994), "Determinants of Timeliness in Product Development", *Journal of Product Innovation Management*, Oxford, UK, Vol. 11 No. 5, pp. 381–396.

Dewar, R.D. and Dutton, J.E. (1986), "The Adoption of Radical and Incremental Innovations: An Empirical Analysis", *Management Science*, Vol. 32 No. 11, pp. 1422–1433.

Frishammar, J., Kurkkio, M., Abrahamsson, L. and Lichtenthaler, U. (2012), "Antecedents and consequences of firms process innovation capability: A literature review and a conceptual framework", *IEEE Transactions on Engineering Management*, Vol. 59 No. 4, p. 519–529Frishammar, J., Kurkkio, M., Abrahamsson, L.

Garcia, R. and Calantone, R. (2002), "A critical look at technological innovation typology and innovativeness terminology: a literature review", *The Journal of Product Innovation Management*, Vol. 19, pp. 110–132.

Gassmann, O. and Schweitzer, F. (2013), *Management of the Fuzzy Front End of Innovation*, Springer International Publishing, Cham.

Gassmann, O., Zeschky, M., Wolff, T. and Stahl, M. (2010), "Crossing the industry-line: Breakthrough innovation through cross-industry alliances with 'Non-Suppliers'", *Long Range Planning*, Vol. 43 No. 5–6, pp. 639–654.

Griffiths-Hemans, J. and Grover, R. (2006), "Setting the Stage for Creative New Products: Investingating the Idea Fruition Process.", *Journal of the Academy of Marketing Science*, Springer Science & Business Media B.V., Vol. 34 No. 1, pp. 27–39.

Gåsvaer, D., Fundin, A., Johansson, P.E. and Langbeck, B. (2016), "Production system development through exploration - challenges and implications", *23rd EurOMA Conference*, Trondheim, Norway.

Herstatt, C. and Kalogerakis, K. (2005), "How To Use Analogies for Breakthrough Innovations.", *International Journal of Innovation & Technology Management*, Vol. 2 No. 3, pp. 331–347.

Hill, T. (2005), *Operations Management*, Palgrave Macmillan, New York.

von Hippel, E. (1986), "Lead Users: A Source of Novel Products Concepts", *Management Science*, Vol. 32 No. 7, pp. 791–805.

Kelley, T. and Littman, J. (2001), *The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm*, Doubleday, New York.

Kennedy, M., Harmon, K. and Minnock, E. (2008), *Ready, Set, Dominate: Implement Toyota's Set-Based Learning for Developing Products and Nobody Can Catch You*, Oaklea Press, Richmond, VA.

Kim, J. and Wilemon, D. (2002), "Strategic issues in managing innovation's fuzzy front- end", *European Journal of Innovation Management*, Emerald, Vol. 5 No. 1, pp. 27–39.

Koen, P., Ajamian, G., Burkart, R., Clamen, A., Davidson, J., D'Amore, R., Elkins, C., et al. (2001), "Providing Clarity and a Common Language To the 'Fuzzy Front End.'", *Research Technology Management*, Vol. 44 No. 2, pp. 46–55.

Kurkkio, M., Frishammar, J. and Lichtenthaler, U. (2011), “Where process development begins: A multiple case study of front end activities in process firms”, *Technovation*, Vol. 31 No. 9, pp. 490–504.

Lager, T., Blanco, S. and Frishammar, J. (2013), “Managing R&D and innovation in the process industries.”, *R&D Management*, Wiley-Blackwell, Vol. 43 No. 3, pp. 189–195.

Liker, J.K. (2004), *The Toyota Way: 14 Management Principles from the World’s Greatest Manufacturer*, McGraw-Hill, New York, NY.

Markham, S.K. (2013), “The Impact of Front-End Innovation Activities on Product Performance.”, *Journal of Product Innovation Management*, Wiley-Blackwell, Vol. 30, pp. 77–92.

Murphy, S.A. and Kumar, V. (1997), “The front end of new product development: a Canadian survey”, *R&D Management*, Vol. 27 No. 1, pp. 5–15.

Oxford. (2003), *Oxford Dictionary of English*, edited by Soanes, C. and Stevenson, A., Oxford University Press, Oxford, England.

Reid, S.E. and De Brentani, U. (2004), “The fuzzy front end of new product development for discontinuous innovations: A theoretical model”, *Journal of Product Innovation Management*, Vol. 21, pp. 170–184.

Saunders, M.L., Lewis, P. and Thornhill, A. (2016), *Research Methods for Business Students*, *Financial Times*.

Schroeder, R.G., Scudder, G.D. and Elm, D.R. (1989), “Innovation in Manufacturing”, *Journal of Operations Management*, Vol. 8 No. 1, pp. 1–16.

Smeds, R. (1997), “Radical change through incremental innovations: generic principles and cultural differences in evolution management”, *International Journal of Technology Management*, Vol. 14 No. 1, pp. 146–162.

Smith, P.G. and Reinertsen, D. (1998), *Developing Products in Half the Time : New Rules, New Tools*, Wiley, New York.

Södergren, B. (2016), *Flaggskeppsfabriken : Styrkor I Svensk Produktion*, Vinnova - Swedish Governmental Agency for Innovation Systems, Sweden.

Thomke, S. and Fujimoto, T. (2000), “Effect of `front-loading’ problem-solving on product development performance”, *Journal of Product Innovation Management*, Vol. 17 No. 2, pp. 128–142.

Tidd, J., Bessant, J. and Pavitt, K. (2005), *Managing Innovation: Integrating Technological, Market and Organizational Change*, John Wiley & Sons, Chichester, England.

Wu, B. (2001), “Strategy analysis and system design within an overall framework of manufacturing system management”, *International Journal of Computer Integrated Manufacturing*, Vol. 14 No. 3, pp. 319–341.

Yamamoto, Y. (2009), “Production management infrastructure that enables production to be innovative”, *16th Annual International EurOMA Conference*, Göteborg, Sweden, June 14-17, 2009.

Yamamoto, Y. (2010), “Interview with an ex-senior manager of a Japanese car manufacturer regarding how the company makes the production system innovative”.

Yamamoto, Y. (2013), *Kaikaku in Prodution Toward Creating Unique Production Systems*, Doctoral thesis, School of Innovation, Degisn, and Engineering, Mälardalen University, Västerås, Sweden.